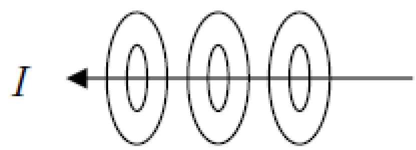
Electromagnetic Fields – Assignment 06

#	Student ID	Student Name	Grade (10)
-			

Delivery Date	

١. يتم تسليم التمرين محلولا في خلال أسبوع من تاريخ التمرين، و يتم حذف درجتين من التمرين عن كل أسبوع تأخير
٢. يتم التسليم لمعيد المقرر مباشرة
٣. تتم أجابه التمرين في نفس ورق الأسئلة

Essay

Q1	**Draw the magnetic field lines around a straight section of wire carrying a current horizontally to the left.**
Sol 1	The magnetic field lines are concentric circles around the wire. With the current running to the left, the field is directed counterclockwise when looking from the left end. So, the field goes into the page above the wire and comes out of the page below the wire. 

Q2	In the relation $\vec{\mathbf{F}} = I\vec{\boldsymbol{\ell}} \times \vec{\mathbf{B}}$, which pairs of the vectors $(\vec{\mathbf{F}}, \vec{\boldsymbol{\ell}}, \vec{\mathbf{B}})$ are always at 90°? Which can be at other angles?
Sol 2	$\vec{\mathbf{F}}$ is always perpendicular to both $\vec{\mathbf{B}}$ and $\vec{\ell}$. $\vec{\mathbf{B}}$ and $\vec{\ell}$ can be at any angle with respect to each other

Q3	If a negatively charged particle enters a region of uniform magnetic field which is perpendicular to the particle's velocity, will the kinetic energy of the particle increase, decrease, or stay the same? Explain your answer. (Neglect gravity and assume there is no electric field.)
Sol 3	The kinetic energy of the particle will stay the same. The magnetic force on the particle will be perpendicular to the particle's velocity vector and so will do no work on the particle. The force will change the direction of the particle's velocity but not the speed.

Problems

Q4	Calculate the magnitude of the magnetic force on a 240-m length of wire stretched between two towers and carrying a 150-A current. The Earth's magnetic field of 5.0×10^{-5} T makes an angle of 68° with the wire.
Sol 4	$F = I\ell B \sin\theta = (150\,\text{A})(240\,\text{m})(5.0\times10^{-5}\,\text{T})\sin 68^\circ = \boxed{1.7\,\text{N}}$

Q5	Suppose a straight 1.00-mm-diameter copper wire could just "float" horizontally in air because of the force due to the Earth's magnetic field $\vec{\mathbf{B}}$, which is horizontal, perpendicular to the wire, and of magnitude 5.0×10^{-5} T. What current would the wire carry? Does the answer seem feasible? Explain briefly.
Sol 5	......

The magnetic force must be equal in magnitude to the force of gravity on the wire. The maximum magnetic force is applicable since the wire is perpendicular to the magnetic field. The mass of the wire is the density of copper times the volume of the wire.

$$F_B = mg \;\rightarrow\; I\ell B = \rho\pi\left(\tfrac{1}{2}d\right)^2 \ell g \;\rightarrow$$

$$I = \frac{\rho\pi d^2 g}{4B} = \frac{\left(8.9\times10^3\,\mathrm{kg/m^3}\right)\pi\left(1.00\times10^{-3}\,\mathrm{m}\right)^2\left(9.80\,\mathrm{m/s^2}\right)}{4\left(5.0\times10^{-5}\,\mathrm{T}\right)} = \boxed{1400\,\mathrm{A}}$$

This answer does not seem feasible. The current is very large, and the resistive heating in the thin copper wire would probably melt it.

Q6	A long wire stretches along the x axis and carries a 3.0-A current to the right $(+x)$. The wire is in a uniform magnetic field $\vec{\mathbf{B}} = (0.20\hat{\mathbf{i}} - 0.36\hat{\mathbf{j}} + 0.25\hat{\mathbf{k}})\,\mathrm{T}$. Determine the components of the force on the wire per cm of length.
Sol 6	We find the force per unit length from Eq. Note that while the length is not known, the direction is given, and so $\vec{\boldsymbol{\ell}} = \ell\,\hat{\mathbf{i}}$.

$$\vec{\mathbf{F}}_B = I\vec{\boldsymbol{\ell}} \times \vec{\mathbf{B}} = I\ell\,\hat{\mathbf{i}} \times \vec{\mathbf{B}} \;\rightarrow$$

$$\frac{\vec{\mathbf{F}}_B}{\ell} = I\,\hat{\mathbf{i}} \times \vec{\mathbf{B}} = (3.0\,\mathrm{A}) \begin{vmatrix} \hat{\mathbf{i}} & \hat{\mathbf{j}} & \hat{\mathbf{k}} \\ 1 & 0 & 0 \\ 0.20\,\mathrm{T} & -0.36\,\mathrm{T} & 0.25\,\mathrm{T} \end{vmatrix} = \left(-0.75\hat{\mathbf{j}} - 1.08\hat{\mathbf{k}}\right)\mathrm{N/m}\left(\frac{1\,\mathrm{m}}{100\,\mathrm{cm}}\right)$$

$$= \boxed{-\left(7.5\,\hat{\mathbf{j}} + 11\,\hat{\mathbf{k}}\right) \times 10^{-3}\,\mathrm{N/cm}}$$

Q7	A 2.0-m-long wire carries a current of 8.2 A and is immersed within a uniform magnetic field $\vec{\mathbf{B}}$. When this wire lies along the $+x$ axis, a magnetic force $\vec{\mathbf{F}} = (-2.5\hat{\mathbf{j}})\,\text{N}$ acts on the wire, and when it lies on the $+y$ axis, the force is $\vec{\mathbf{F}} = (2.5\hat{\mathbf{i}} - 5.0\hat{\mathbf{k}})\,\text{N}$. Find $\vec{\mathbf{B}}$.
Sol 7	....

We apply Eq. to each circumstance, and solve for the magnetic field. Let $\vec{\mathbf{B}} = B_x\hat{\mathbf{i}} + B_y\hat{\mathbf{j}} + B_z\hat{\mathbf{k}}$.

For the first circumstance, $\vec{\boldsymbol{\ell}} = \ell\,\hat{\mathbf{i}}$.

$$\vec{\mathbf{F}}_B = I\vec{\boldsymbol{\ell}} \times \vec{\mathbf{B}} = (8.2\,\text{A})\begin{vmatrix} \hat{\mathbf{i}} & \hat{\mathbf{j}} & \hat{\mathbf{k}} \\ 2.0\,\text{m} & 0 & 0 \\ B_x & B_y & B_z \end{vmatrix} = (-16.4\,\text{A}\cdot\text{m})\,B_z\hat{\mathbf{j}} + (16.4\,\text{A}\cdot\text{m})\,B_y\hat{\mathbf{k}} = (-2.5\hat{\mathbf{j}})\,\text{N} \;\rightarrow$$

$$B_y = 0\,;\; (-16.4\,\text{A}\cdot\text{m})\,B_z = -2.5\,\text{N} \;\rightarrow\; B_z = \frac{2.5\,\text{N}}{16.4\,\text{A}\cdot\text{m}} = 0.1524\,\text{T}\,;\quad B_x \text{ unknown}$$

For the second circumstance, $\vec{\boldsymbol{\ell}} = \ell\,\hat{\mathbf{j}}$.

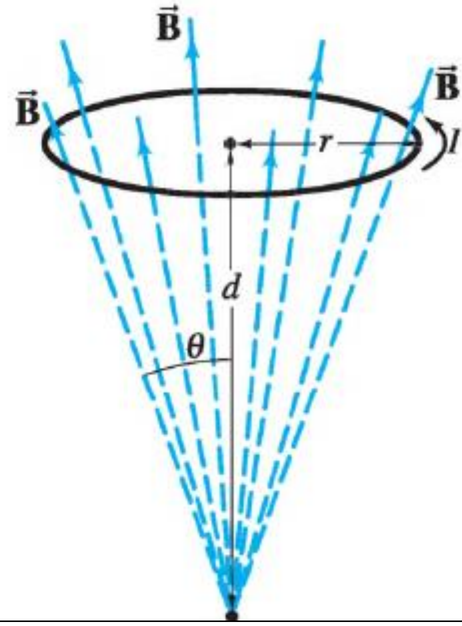
$$\vec{\mathbf{F}}_B = I\vec{\boldsymbol{\ell}} \times \vec{\mathbf{B}} = (8.2\,\text{A})\begin{vmatrix} \hat{\mathbf{i}} & \hat{\mathbf{j}} & \hat{\mathbf{k}} \\ 0 & 2.0\,\text{m} & 0 \\ B_x & 0 & 0.1524\,\text{T} \end{vmatrix} = (2.5\,\text{N})\,\hat{\mathbf{i}} + (-16.4\,\text{A}\cdot\text{m})\,B_x\hat{\mathbf{k}} = (2.5\hat{\mathbf{i}} - 5.0\hat{\mathbf{k}})\,\text{N} \;\rightarrow$$

$$(-16.4\,\text{A}\cdot\text{m})\,B_x = -5.0\,\text{N} \;\rightarrow\; B_x = \frac{5.0\,\text{N}}{16.4\,\text{A}\cdot\text{m}} = 0.3049\,\text{T}$$

Thus $\vec{\mathbf{B}} = \boxed{(0.30\,\hat{\mathbf{i}} + 0.15\,\hat{\mathbf{k}})\,\text{T}}$.

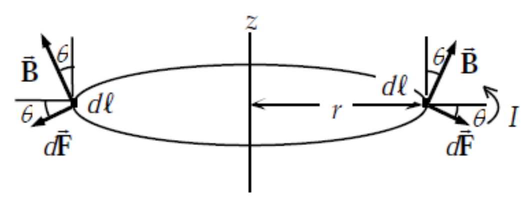
Q8

A circular loop of wire, of radius r, carries current I. It is placed in a magnetic field whose straight lines seem to diverge from a point a distance d below the loop on its axis. (That is, the field makes an angle θ with the loop at all points, Fig. , where $\tan\theta = r/d$.) Determine the force on the loop.



Sol 8

The net force on the current loop is the sum of the infinitesimal forces obtained from each current element. From the figure, we see that at each current segment, the magnetic field is perpendicular to the current. This results in a force with only radial and vertical components. By symmetry, we find that the radial force components from segments on opposite sides of the loop cancel. The net force then is purely vertical. Symmetry also shows us that each current element contributes the same magnitude of force.

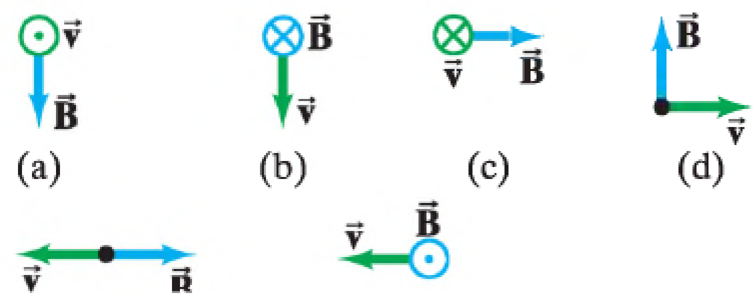


$$\vec{F} = \int I d\vec{\ell} \times B = -IB_r\hat{k}\int d\ell = -I(B\sin\theta)\hat{k}(2\pi r) = \boxed{-2\pi IB\frac{r^2}{\sqrt{r^2+d^2}}\hat{k}}$$

Q9	An electron is projected vertically upward with a speed of 1.70×10^6 m/s into a uniform magnetic field of 0.480 T that is directed horizontally away from the observer. Describe the electron's path in this field.
Sol 9	The magnetic force will cause centripetal motion, and the electron will move in a clockwise circular path if viewed in the direction of the magnetic field. The radius of the motion can be determined. $F_{max} = qvB = m\frac{v^2}{r} \rightarrow r = \frac{mv}{qB} = \frac{(9.11\times10^{-31}\,\text{kg})(1.70\times10^{6}\,\text{m/s})}{(1.60\times10^{-19}\,\text{C})(0.480\,\text{T})} = \boxed{2.02\times10^{-5}\,\text{m}}$

Q10

Find the direction of the force on a negative charge for each diagram shown in Fig. , where $\vec{v}$ (green) is the velocity of the charge and $\vec{B}$ (blue) is the direction of the magnetic field. (⊗ means the vector points inward. ⊙ means it points outward, toward you.)



Sol 10

Since the charge is negative, the answer is the OPPOSITE of the result given from the right hand rule applied to the velocity and magnetic field.

(*a*) left
(*b*) left
(*c*) upward
(*d*) inward into the paper
(*e*) no force
(*f*) downward